Research Journal of Management Sciences ISSN 2319–1171
Vol. **4(5),** 1-5, May **(2015)** *Res. J. Management Sci.*

Global Climate Change: Solar Energy is the harbinger for Sustainable Development of India

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Available online at: www.isca.in, www.isca.me
Received 15th March 2015, revised 4th April 2015, accepted 2nd May 2015

Abstract

Green House Gas emission due to use of fossil fuel is increasing the temperature of the World. Global temperature rise is not restricted to any locality. It will affect every country of the world irrespective of their per capita energy consumption/ level of Development. Every country has to change their energy mix to restrict temperature rise. We reviewed the technical advancement of Solar Technology and its impact on projected cost per unit. India has to fully exploit its Solar potential linearly to change India`s energy mix, restrict temperature rise and sustainable development.)

Keywords: Band Gap, Dual Axis Tracking, Electron, Ecosystem, Energy, Exergy, Green House Gas Emission,, Global Climate Change, Hole, Life Cycle Exergy Analysis, Multi Junction, Multi spectrum, Nano Technology, NREL, Photo Voltaic, Photon, OECD.

Introduction

World energy demand mainly depends upon the utilization of fossil fuels, The fossil fuels are responsible for the release of green house gases. The green house gas is responsible for global climate change resulting in global warming. Today World urban population stands at 54% with economic output of 75%, green house gas emission of 80% after consuming 80% of world energy demand. The increased urbanization will invite more Global Climate Change. Incessant emission of greenhouse gases will responsible for more global warming and subsequent temperature rise. Global climate change will severely affect the environment resulting in long-lasting changes in all components of the Ecosystem Limiting climate change would need substantial and sustained reductions in greenhouse gas emissions which, together with adaptation to changed situation can limit climate change risk[2].

Table-1
United Nation Population Projection

Year/Population	2020	2030	2040	2050
Population in billions	7.7	8.5	9.1	9.5

The Energy demand is based on Population growth, Economic Development (GDP growth), Per Capita income and consumer price Index. The world population is growing rapidly particularly in South Asia and African Countries. In addition to above, It has positive effect on energy demand of the World.

GDP growth will be more in NON OECD Countries particularly in BRICS countries. World Energy demand will increase considering the population and Economic growth of African countries and South Asian countries and rapid urbanization of World.

Table-2
World GDP growth projection

Year	2001-2007	2012-2017	2018-2030	2031-2050
GDP growth	2.7	3.4	3.3	2.4
OECD	2.1	2	2.2	1.9
Non OECD	6.9	6.9	5.1	3

(Ref: OECD Economic Outlook 2012)

Table-3
World Energy Outlook

Year	2005	2020	2035	2050
Energy Billion TOE	11.3	14.4	17.3	20

Considering the related factor, demand of Energy is increasing steadily. The existing energy demands is generally supplied by use of fossil fuels. The Green House Gas emission is increasing steadily as per the use of fossil fuels in the World.

Table-4
World GCG projection

Year	1900	2000	2015	2025	2035	2050
Global CO2 equivalent (Gton CO2/Yr	7.47	41.12	55.89	69.6	86.69	115.28
Atomospheric CO2equivalent ppm	288.2	377.2	404.57	418.11	525.57	680.79

Ref: www.co2.org, India is not an exception to this. The demand of energy is rising exponentially due to population growth, urbanization and economic growth.

Table-5
India Population Growth: (Census 2011,PFI2007)

Year	1951	1961	1971	1981	1991	2001	2011	2021	2031	2041	2050
Population In crore	36	44	55	68	84	103	121	137	152	165	175
Rural Population in crore	30	36	44	52	62	74	83	89	93	95	98
Urban Population crore	6	8	11	16	22	29	38	48	59	70	77

Ref: (Personal Computation based on Census 2011, Population Foundation of India 2007)

Table-6
India Energy Demand (Power Grid Corporation Desert Power India 2050)

Year	2012	2021-22	2031-32	2041-42	2050
Installed capacity requirement in Gw	200	372	712	1067	1388

Table-7
Calorific Value of fossil fuels

Fuel	Calorific Value MJ/Kg	CO_2 Released per kg of fuel	CO_2 per Energy Kg/Mj
Coal	26	2.4	0.09
Oil	42	3.2	0.08
Gas	55	2.8	0.05

The simplest scenario is to stabilize CO2 in atmosphere by mid century is one in which photovoltaic's and other renewable are used for electricity (10TW), hydrogen for Transport (10TW) and fossil fuel for residential and Industrial use (10TW).[3]

Objective: Can we afford to depend on fossil fuel to meet our energy requirements. The answer is clear NO. We have to go for alternative energy for effective utilization of Technology for sustainable development. Solar Energy is the one of the best option to meet the requirements to avoid global warming. The documents reviewed for this paper are mentioned in reference

Methodology

This presentation is based on my experience in the field of Energy Management and literature review of related documents in related Global climate Change and its mitigation in the form of Solar Energy. Literature review was followed by site visit of various parts of India , training in latest advancement in solar Technology and limited focus group discussion

Technical Discussion: Advantage Solar power: Solar Technology is moderately advanced No green house gas emission. Limited maintenance expenditure and Considerably cheaper than electricity from coal if cost of carbon capture is factored in. The cost per Solar unit is coming down very fast. It will be comparable to that of fossil fuel unit within 10 years. if Innovation in Technology increased, it can increase the efficiency up to 40% to make it competitive to that of fossil fuel. Solar Energy gas great promise for solving global warming and fossil fuel depletion problems!.India has to fully utilize its solar power potential for better energy mix by avoiding

Solar Energy disadvantage: No night time and cloudy days availability

Site requirements of Solar Power: Energy is the prime requirement of development. Without Energy, any locality can not be improved. The selection of suitable project areas involves physical, demographical, economic, policies, and environmental factors. Land Use, Geo Technical, Accessibility, Soil Erosion Health and Safety, Cultural, Archaeological, Socioeconomic, Grid connection, water availability.

Table-8
India Solar Potential

No	Solar Power Capacity	Installed Capacity as on 31.12.2014
Solar Power in GW	749	3

Ref: MNRE Govt of India

Solar Cell Generation[4]: **First Generation Solar Cell**: The first generation solar cell made from silicon cover 80% of Solar Panel manufactured in World.

Single crystal silicon wafers (c-Si). The efficiency is around 15 to 18%.
Advantages Spectral absorption range is broad. carrier mobility is high.
Disadvantages: Requires expensive manufacturing technologies. Ingots manufacturing process is a highly energy intensive.

Second Generation Solar Cell: The Polycrystalline Silicon wafer cost is less to that of Monocrystalline. The second generation solar cell is made of thin film deposits of Semiconductor

Amorphous silicon (a-Si) Polycrystalline silicon (poly-Si) Cadmium telluride (CdTe) Copper indium gallium diselenide (CIGS) alloy

Advantage: Lower cost compare to First generation and reduced silicon requirement 150Kwh energy required to make 1m2 Thin film solar cell compare to 550Kwh energy required to 1m2 silicon based solar module. 20 to 30gram Si is required to make 1m2 thin film solar module compare to 1Kg silicon for 1m2 mono crystalline solar module

Disadvantage: efficiency of thin film solar cell is less compare to first and Second Generation Solar Cell

Third Generation Solar Cell: This cells are supposed to cross the Shockley Queisser efficiency Limit (31-41%

Nanocrystal solar cells, Photo electrochemical (PEC) cells, Gr‰etzel cells, Polymer solar cells and Dye sensitized solar cell (DSSC)

Advantages: Low Energy, High throughput processing technologies Disadvantage: The efficiency is lower compare to Silicon Solar Cell

Fourth Generation Solar Cell: Hybrid - inorganic crystals within a polymer matrix
Advantage: Lower Cell cost, Disadvantage: Lower efficiency

Table-9
PV research cell efficiency (Ref: NREL Best Research cell Efficiency, Rev: 141218)

No	PV Cell	Efficiency in%	Remarks (area required for Kw2)
A	Crystalline Silicon Cell		7m2/Kw
1	Single Crystal(concentrate)	27.6	-
2	Single Crystal(Non concentrate)	25	-
3	Multi Crystalline	20.4	8m2/Kw
4	Thin Film Crystal	21.2	-
B	Thin Film Technologies		-
5	CIGS (concentrate)	23.3	-
6	CIGS	21.7	10m2/Kw
7	Cd Te	21.5	10m2/Kw
8	Amorphous Silicon	13.4	-
C	Multijunction		-
9	Three Junction (concentrate)	44.4	-
10	Three Junction (non concentrate)	37.9	-
11	Two Junction (concentrate)	34.1	-
12	Two Junction (non concentrate)	31.1	-
13	Four Junction (concentrate)	46	-
14	Four Junction (non concentrate)	38.8	-
D	Single Junction Ga-As		-
15	Single Crystal	26.4	-
16	concentrator	29.1	-
17	Thin Film Crystal	28.8	-
D	Emerging PV		-
18	Dye Sensitized Cell	11.9	-
19	Pervoskite Cells	20.1	-
20	Organic Cell	11.1	-
21	Organic Tandem Cell	10.6	-
22	Inorganic Cell	11.1	-
23	Quantum Dot Cell	9.2	-

Table-10
Photovoltaic Market

No	Photo Voltaic Market	PV System Cost	Energy Position	Potential Technology
2000=05	1GW	$6/w	Limited Contribution	Wafered Silicon
2010-15	10GW	$3/w	Cost effective Building integrated application	Wafered silicon
2020-25	100GW	$1.5/w	Large distribution	Wafered silicon Thin Film Nano
2025-50	1000GW	$1/w	Complete Dominance	Thin Film Nano

(Ref: Sun Power High efficiency Solar Cell)

Table-11
Photovoltaic Cost segregation

Cost	Module Assembly	Installation	Ingot Growth	Wafering	Cell Processing
In %	21	31	20	14	14

The Silicon Solar cell efficiency now is around 18%. The Cost per unit of Solar Energy is US$0.15. If we reduce the cost to US$0.06, then solar energy can compete with other type of commercial energy. To reduce the cost to USD$0.06, efficiency of solar cell will have to increase up to 40%.

The Technological Innovation, Product Optimization, Economies of Scale production and Extended lifetime of PV System are required to reduced cost of Solar Electricity. The Technological innovation factors essential for this is Reduced wafer thickness, increased cell size, improvement crystal growth technology, improvement in slicing technology and automation.

All solar modules more than 1Mw should have dual axis tracking Technology. Solar tracking is a device for orienting PV Panel towards sun throughout day. Single axis tracking technology will increase power output by 10-17% and dual axis tracking will increase the power output by 30 -40%. The cost will be increased by around 20%. Remote operation of dual tracking system will provide reliability of system.

Next Generation Technology: Existing PV cell has two drawback in the form of reduced efficiency and increased manufacturing cost. Reduced efficiency is due to incoming photon having either excess band gap energy and reduced band gap energy. These two effect has alone account for loss of around 70% of energy incident on cell[5]. Nano Technology has the potential to reduce cost and increased efficiency in the form of i. Silicon nanostructures, ii. Band gap engineering of silicon iii. Applications could be tandem solar cells and energy selective contacts for hot carrier solar cells, iv. Fabrication of silicon nanostructures consisting of quantum well and quantum dot super lattices to achieve band gap control[6]

Nanotechnology has the capabilities to innovate in the form of efficiently capture, store, and transfer energy and resulting in addressing both the short term and long term energy challenges. Nano Technology is creating a ray of hope in clouded environment going to be created by Global Warming. When productivity of all sectors is going to be reduced by Global Warming , Use of Nano Technology is going to compensate the losses in different segment of economy.

Nano Technology has a major role in increasing the efficiency and reducing the cost keeping the quality of product constant. Recent research indicate that concentration of light intensity can be increased by 15 times compare to normal solar cell. Nano Technology incorporation into thin film has established has increased efficiency at reduced cost in the form of multiple reflection for increased absorbtion ,reduced losses in terms of shorter path for movement of Hole and Electron and band gap adjustment of various layers by varying the size of Nano Particles[7].

The use of nanowires for photovoltaic applications constitutes a promising approach due to High aspect–ratio. The anti–reflective and light trapping properties of vertical nano wires can improve light absorption capacity. Nano wire can be long enough to increase light absorption capacity and can be thin enough to increased carrier movement for better efficiency

Nano Wire Properties: Reduced size, Increased absorptive, Reduced reflectivity, Efficient electron transport, Reduced Recombination, Very narrow pointed structures.

Greater area made of p-n junctions is exposed to sunlight. increases absoptivity

The amount of power available depends upon the type/area of material, intensity of sunlight and wavelength of sunlight. Nano material has the capability for increased absorbtion and reduced reflection of Photon. Nano Material has the capability to reduce temperature of solar array for increased efficiency. Nanosolar cell has the capability to reduce the energy unit price of solar energy

so that it can compete with other commercial source of energy. It is recommended to have increased research on Nano Solar cell for increased efficiency and Nano material for energy storage for use in night time. Nano Technology in the form of carrier multiplication can increase the efficiency of Solar Cell from around 20% to 65%.[8] In recent years, inorganic semiconductor nanocrystals (also known as Quantum Dots, QDs) have been found to be promising for next generation solar cell[9].

Future research area: Generally reducing the cost and increasing the performance of PV Technologies is the primary research focus. In addition to above lifetime of PV component and value of PV electricity cannot be neglected[10].

Following sector need increased interest, Multiple energy level solar cells, Multiple spectrum solar cells, Multiple temperature solar cells, Multi Junction solar cells, Improved method of integrating renewable energy into building, electricity grids and other distribution system[11].

Sustainability: Solar System must prove its commitment towards sustainability in production and consumption process. Exergy is the maximum theoretical work obtained from system at a specified state from given environment. Life Cycle Assessment is method to analyze the environmental impact of product. The Life Cycle Exergy Analysis(LCEA) is shown to be advantages in the study of solar based energy systems and is recommended as a suitable tool for the design and evaluation of renewable energy systems[12].

Constraint: Climate Change due to increased Green House Gas Emission may influence cloud cover rainfall pattern and this can affect resource potential of solar energy in different parts of the World.[13] So during assessment of Solar Energy, climate change variability should not be ignored

Conclusion

Solar Energy Conversion consist of large family of different technologies capable of meeting variety of energy service needs. The various solar technologies having different maturities and their applicability depends upon local policies and govt policies to support their adaptation[14]. Solar Energy is going to be cost effective technology in future. New thin film technologies are being developed. The cost effectiveness of future Solar Technology is based on Nano silicon and other Third generation technologies Solar Technology is the only technology to protect the World from Global Warming subjected to invention of suitable energy storage system. India has to take active steps to harness Solar Potential to change Energy Mix by 2050 for sustainable development and reduce Global warming

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